SEQUENTIAL DISINFECTANT TREATMENT FOR WASTE WATER

The present invention relates generally to a method and apparatus for treating waste water and, more specifically, to a method and apparatus for treating wastewater to reduce bacterial contamination thereof through sequential dosing of a stream or column of waste water with a single disinfectant agent such as chlorine.

Pollution attributable to the discharge of waste water into bodies of water such as rivers, lakes, estuaries and larger bodies of water has long been recognized as a significant public health problem due to the presence therein of bacterial and viral microorganisms posing threats to humans and other animal life. Untreated waste water typically carries fecal material, which includes coliform bacteria, posing a significant health risk. Chlorination is a well known method of treating waste water to reduce the levels of bacterial and viral microorganisms to recognized, acceptably low levels. Dissolution of chlorine in water forms a mixture of hypochlorous (HClO) and hydrochloric (HCl) acids. The latter completely dissociates into hydrogen and chlorine ions, while the former only partially dissociates into hydrogen and hypochlorite ions, relating to the pH of the water. In either case, the chlorine effectively destroys and suppresses the bacterial and viral microorganisms present in the wastewater.

Chlorine also, unfortunately, reacts with other substances typically contained in waste water to form, over time, other compounds. For example, chlorine reacts with ammonia to form chloramines. Thus, over time, chlorine is depleted from the waste water or, stated another way, chlorine demand is time-

dependent. The amount of active chlorine present in waste water at any given time is referred to in the art as the "free chlorine residual", or merely the "residual". Residual may be determined as the difference between the demand to the time of determination and the total chlorine dosage introduced into the waste water.

In stage one sewage treatment plants, a common method of disinfecting waste water is by injecting gaseous and/or liquid chlorine into that water as it enters a "contact tank". In such a disinfection process, it is important to provide a sufficient dose of chlorine to 'contact' a body of flowing waste water effluent for a sufficient period of "contact time" to effect disinfection of the water to an acceptably low level of contamination. The dosage and contact time must be sufficient to achieve the desired level of disinfection without a large excess of residual chlorine in the treated water. For example, a typical public health standard may require disinfection of the waste water so that there are no more than 5000 coliform colonies per milliliter ("cfu/ml") in the treated water with a residual chlorine level of about 0.1 part per million (ppm).

A typical design for a "contact tank" is shown in Figures 1 and 2. In such a contact tank, the waste water is disinfected by providing an initial, single dose of chlorine to the water as it enters the contact tank. As shown in Figure 2, the chlorine is typically injected throughout, or across the cross-sectional area of, a moving waste water column entering the contact tank at a single dosing location. This dose of chlorine is carried with the water in plug flow fashion and disinfects that water as it passes through the tank. A typical problem with such a single dosage disinfection process is that chlorine has a short half-life in water. Thus,

the initial dosage of chlorine must be carefully selected to be of sufficient magnitude to ensure that the free chlorine residual will be sufficient during the time of passage through the contact tank to disinfect the water to a desired low level of contaminants without an unacceptable residual chlorine level remaining at the end of the treatment process.

A significant problem with the traditional, single point dosage chlorination process is attributable to application of chlorine only at the entrance to the contact tank, as it is very difficult to accurately judge the proper, single chlorine dose to be added to the waste water. The proper dosage must be adjusted according to the bacterial loading and inherent organic chlorine demand of the waste water, as well as the amount of effluent in that waste water. An additional problem is due to the extended residence time of each portion of the flow of waste water in the contact tank, typically about 30 minutes for a tank about 70 meters long. Because chlorine is injected into the waste water at a single point, the aforementioned "plug flow" results. As each "plug" or segment of waste water flows through the contact tank, the chlorine reacts with the inherent organic material and bacteria in the surrounding waste water and with any effluent in that waste water. Those reactions reduce the free chlorine residual available for treatment of the harmful microorganisms and may, in some circumstances, reduce the free chlorine residual to a level insufficient for effective treatment. Thus, the proper single chlorine dosage at the contact tank entrance must be varied to accommodate flow rate, the length of the flow path through the contact tank, bacterial and viral contaminant loading (bacterial loading usually being used as the standard), the concentration of effluent in the waste water, and the inherent chlorine demand

attributable to organics in the waste water. Failure to regulate the chlorine dosage properly may result in either an unacceptably high level of microorganism colonies at the end of the treatment process or an unacceptably high residual chlorine level. As the former result is more undesirable, the conventional approach is to introduce an excessive chlorine dose, resulting in excessive residual chlorine but at least complying with the requisite public health standards. However, such an approach requires a relatively larger chlorine generation capacity, with attendantly larger capital and operating expenses.

Finally, as previously noted, chlorine exhibits a short half-life. Thus, using the plug flow of waste water to "carry" a single chlorine dose along full length of the flow path through the contact tank for the extended tank residence time is inefficient due to the resulting deterioration of the chlorine concentration.

The problems associated with single dosage processes are further compounded by variations in the composition of the waste water. This can be particularly true in Hong Kong and other locales where the entire sewage system utilizes sea water or another water source exhibiting highly variable bacterial loading and organic content. Because sea water has exceptional seasonal variation in composition, including its inherent organic content and bacterial loading, the continuous attainment of both the desired bacterial count standard and the residual chlorine level standard in the treated water is very difficult. An inability to meet both standards is unacceptable where a water permit or other environmental regulation sets specific limits for both bacterial counts and residual chlorine levels.

As noted above, the typical treatment process applies a high dosage of chlorine at the single initial injection site to ensure adequate disinfection for the entire waste water flow path. However, the resulting chlorine residual in the treated water is unacceptably high from an environmental standpoint due to harm to fish and other forms of marine life, which impairs commercial harvest yields of marine life and may also have an adverse affect on fishing-dependent tourism.

Technologies other than chlorine dosage, such as ultraviolet and ozone treatments, have been developed to disinfect waste water. These alternatives are unacceptable in many locations, however, due to higher capital and operating expenses than those associated with the above-described conventional chlorination technique. Such technologies may also present safety and environmental problems not associated with the conventional chlorination technique.

BRIEF SUMMARY OF THE INVENTION

The present invention includes a method and apparatus for sequentially dosing waste water flowing along a path, such as in a contact tank, at multiple locations along the length of the flow path. The invention affords the advantages of administering doses of disinfectant at spaced points along the flow path such that an effective level of disinfectant is maintained throughout the length of the flow path to achieve the desired reduction in bacterial and viral microorganisms while employing a lesser total quantity of disinfectant than is required with a traditional single-dosage technique, thus providing an effective treatment process while reducing the residual chlorine level at the end of treatment.

One embodiment of the invention encompasses a method of "graded multi-point dosing" (GMPD), by which a disinfectant such as chlorine is injected at a plurality of points spaced along the length of an elongated flow path through a treatment vessel such as a contact tank. Preferably, the disinfectant may be injected into a waste water stream moving along the flow path at about the same time at the plurality of points so that an effective level of disinfectant can be maintained within the stream as it travels the flow path. The doses of disinfectant are also preferably injected proportionally, as by relative volume, at the plurality of points. The dose of disinfectant is preferably the largest at the upstream-most injection point, since the microorganism loading, concentration of effluent and inherent organic disinfectant demand in the waste water will be the highest prior to any treatment. Downstream of the first injection point, the foregoing constituents of the waste water will be relatively lesser in magnitude, requiring a lesser dosage of disinfectant to maintain an effective residual level of disinfectant. As used herein, an "effective level" of disinfectant means an effective level of disinfectant to kill or otherwise render substantially harmless at least one selected bacterial or viral microorganism present in the waste water. If more than two injection points are employed, the dosage required to be injected at the third, fourth and each subsequent injection point will usually be smaller than the dosage injected at the injection point upstream therefrom and greater than the dosage employed at an injection point downstream therefrom, such that the dosages are graded.

Another embodiment of the invention encompasses an apparatus for injecting doses of disinfectant at a plurality of spaced points along a flow path

through a vessel such as a contact tank. The apparatus is configured with an inlet for receiving a stream of waste water and at least two injectors or groups of injectors spaced at dosing locations along the flow path for injecting doses of disinfectant into the waste water stream before the stream exits the vessel at an outlet thereof. A source of disinfectant is provided, as is a conduit arrangement, which may take the form of a manifold, for delivering disinfectant from the source to the injectors. Preferably, a flow control device is associated with each injector or injector group for a single dosing location so that the dosage of disinfectant delivered into the flow path by each injector or group may be selected and varied. A controller may also be provided to initiate the flow control devices to adjust the dosage level of disinfectant delivered by each injector, and one or more sensors provided to sense conditions in the waste water at one or more locations to provide signals, responsive to which the controller may initiate the flow control devices to vary the disinfectant flow to each dosing location.

In utilizing the method and apparatus according to the invention, it is desirable to employ a dosing liquid, or diluent, as a carrier for the disinfectant from the source to the injection points, and preferably in conjunction with the previously-described GMPD technique. Using a dosing liquid and injecting disinfectant carried thereby into the waste water flow path at a plurality of points instead of employing conventional single point injection does not require an amount of disinfectant in excess of that required by the conventional technique, and in fact may be less. Instead of using the entire volume of waste water in plug flow as a transport vehicle to carry the disinfectant throughout the length of the flow path, the vehicle comprises only the far lesser volume of dosing liquid.

Because the smaller volume (usually by at least several order of magnitude) of dosing liquid transfers the disinfectant to the waste water, the inherent disinfectant demand of the dosing liquid vehicle is far less than that of the waste water stream conventionally employed. Thus, more active disinfectant may be transferred from the source to the waste water stream to effect disinfection thereof. Consequently, using GMPD, substantially less disinfectant may be employed to effectively reduce microorganism concentration (such as, for example, coliform bacteria count) while also reducing the disinfectant residual at the end of the flow path.

The apparatus of the present invention may be added to an existing waste water treatment contact tank or other vessel at a relatively nominal capital cost in comparison to that required to implement an ultraviolet or ozone disinfectant technique, and with substantially no increase in operating cost after installation, in comparison to conventional, single point disinfectant injection.

The disinfectant employed with the invention may comprise any suitable chemical agent effective for reducing the concentrations of bacterial and viral microorganisms present in the waster water to be treated. Chlorine in various forms is a preferred disinfectant, and may include, by way of example only, chlorine in liquid or gaseous form, sodium hypochlorite (NaOCl), disinfectants including a chlorine component, and mixtures of the foregoing. Other disinfectants as known in the art and suitable for use with the multi-point injection technique according to the method and apparatus of the invention may also be employed. The disinfectant source may comprise a pressurized vessel, a vessel

from which disinfectant may be pumped, a generator to provide disinfectant in gaseous form, or other sources as known in the art.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is an overhead view of a contact tank and chlorine injection line according to a prior art configuration;

Figure 2 is a cross-sectional view, taken across line 2-2 of FIG. 1, of a portion of the contact tank of FIG. 1 looking along the passageway therethrough in a direction of waste water flow;

Figure 3 is an overhead view of a first embodiment of the apparatus of the present invention; and

Figure 4 is an overhead view of a second embodiment of the apparatus of the present invention.

DESCRIPTION OF THE INVENTION

Referring to Figure 3, an exemplary contact tank 10 with a sinuous passageway 15 defining a flow path therethrough is depicted. Other possible configurations for contact tank 10 are, of course, readily apparent to one of ordinary skill in the art. A stream of waste water enters contact tank 10 at an inlet 20 and flows along passageway 15 as depicted by the arrows shown therein to exit contact tank 10 at outlet 25. Effluent-containing waste water may be provided from any source, such as, for example, freshwater or salt water sewage from sanitary sewers, storm water sewage (runoff), manufacturing or processing plant waste water, and agricultural waste water from farming or processing, including

without limitation animal waste from cattle feed lots and other facilities for raising, for example, pigs, chickens and other livestock. Other sources of waste water are, of course, possible.

A disinfectant, preferably chlorine, is provided from any suitable source 30. The chlorine can be, for example, gaseous chlorine, liquid chlorine or sodium hypochlorite (NaOCl). The source may be pressurized to aid the flow of disinfectant, optionally mixed with a dosing liquid, through a conduit arrangement such as manifold 35 to each of a plurality of injectors 40 in communication with passageway 15. A plurality of injectors 40 may be ganged or grouped at a given location in passageway 15 and arranged to introduce disinfectant into the waste water stream across a large portion of the cross-section thereof, such an arrangement being known in the art and previously described and depicted with respect to FIG. 2

A dosing liquid may be provided from any suitable source, such as waste water or other liquid suitable for carrying chlorine. The dosing liquid can, alternatively, be fresh water and/or salt water, for example. Referring to FIG. 3, the source of dosing liquid in this instance is the waste water stream itself, a portion of which is diverted from the primary flow path through contact tank by dosing line 45, which carries the diverted flow to pump 50, disinfectant being added to the dosing liquid flow at the intake end of pump 50 in desired, substantially metered proportion controllable by a metering device, which may take the form of a valve 55. A dedicated mixing chamber may be employed to mix the disinfectant and the dosing liquid or, as shown, pump 50 may be employed as a mixing chamber.

Dosing liquid with the entrained disinfectant, or in some embodiments a liquid disinfectant alone, is carried to injectors 40 through the branches of conduit arrangement or manifold 35, each branch having associated therewith a flow control device, which may take the form of a valve 60, to regulate flow to one or more injectors fed by that particular branch. Valves 60 may be employed to regulate the amount of disinfectant, or dosing liquid carrying disinfectant, to their associated injectors, and to proportion, or grade, the relative flow of disinfectant to each injector 40. Preferably, each valve is separately controlled. While valves 60 may comprise manually operated valves, it is preferably that the valves be remotely operable valves, such as servo valves, and also preferable that a controller 65 be operably coupled to each valve 60 (and, optionally, as shown in a broken line to valve 55) so that the flow of disinfectant to each injector may be remotely, separately and, as desired, automatically regulated in response to operator input or to sensed conditions in the flow stream of waste water in passageway 15. Controller 65 may comprise, for example, a dedicated programmable logic controller, or a suitably programmed personal computer. As implied above, controller 65 may also be operably connected to one or more sensing devices 70 placed in communication with passageway 15, sensing devices 70 being used to monitor, for example, disinfectant residual, bacterial content, organic content, or other parameter or parameters having utility in determining a dosage of disinfectant required to be added to the waste water stream at the location of each injector or group of injectors 40 at each dosing location spaced along passageway 15. Sensing devices 70 are preferably placed upstream of each associated dosing location, so as to monitor the effects of the

disinfectant introduced into the flow stream at an immediately upstream dosing location. In the example shown in Figure 3, four dosing locations, designated at 1-4, are located in contact tank 10 along passageway 15. The dosing locations may be substantially equally spaced along passageway 15, as shown in FIG. 3, or non-uniform spacings may be employed. As will be appreciated by those skilled in the art, the number of dosing locations and the number of dosing outlets (e.g., injectors 40) at each dosing location may be varied according to the waste water flow rate, the desired dosage of disinfectant, the concentration of disinfectant in a dosing liquid, and the disinfectant demand of the waste water flow. The injectors 40 at each dosing location are preferably positioned to effectively disperse the disinfectant into the waste water across the entire cross section of passageway 15 at the dosing location. It is also contemplated that mixing devices may be employed at the dosing locations to effect more rapid dispersion of the disinfectant into the waste water stream.

Referring to FIG. 4 of the drawings, a second embodiment of the apparatus of the present invention is depicted. Elements of the second embodiment which correspond to those described with respect to the first embodiment are, for clarity, identified by the same reference numerals. In addition to the elements of the first embodiment, the second embodiment includes one or more pretreatment tanks or units 90, which may be used to remove large solids, including particulates, from the waste water stream prior to treatment in contact tank 10. Known techniques for such removal include screening, settling, and filtration. Such pretreatment tanks 90 may enhance the effectiveness of the treatment in contact tank 10 by reducing the presence of microorganism-carrying solid waste and providing a

more easily-treatable waste water stream devoid of materials which, over time, would otherwise accumulate in passageway 15, coat, clog or even damage injectors 40, and inhibit dispersion of disinfectant into the waste water stream. One or more post-treatment tanks or units 100 may also be employed to receive waste water discharged from outlet 25 of contact tank 10. For example, a tank 100 may comprise a settling tank.

The following example illustrates aspects of the invention, although the invention is not limited by or to this example. A flow of 500 cubic meters per hour of waste water is introduced into a 70 meter (passageway length) contact tank. A chlorine dose of about 10 kilograms per hour is entrained in a dosing liquid flow of about 3.6 cubic meters per hour. The dosing liquid can be fresh water or salt water. The chlorine-containing dose flow is introduced proportionally (by volume) and at the same time, to the waste water stream at a plurality of (in this example, four) dosing locations along the passageway length of the contact tank. In this example, the 3.6 cubic meter per hour dose flow, containing 10 kilogram per hour of chlorine, is proportionally introduced into the waste water stream by GMPD at the various dosing locations. Referring to the following Table 1 in conjunction with the dosing locations shown in FIGS. 3 and 4, about 50% of the dosing liquid is introduced at Location 1, about 28% of the dosing liquid is introduced at Location 2, about 14% of the dosing liquid is introduced at Location 3, and about 8% of the dosing liquid is introduced at Location 4. As also noted, a fifth dosing location may also be employed, the use of which would, of course, cause the percentages of dosing liquid introduced at the other dosing locations to vary. Optionally, a Location 5 may only be used intermittently, such as where sensing

devices are employed in passageway 15 and detect particularly troublesome remaining microorganism concentrations after the waste water stream passes Locations 1-4. The effect of each of these disinfectant doses, as to the reduction in coliform counts and the residual chlorine levels, is monitored by taking regular samples of waste water at the end of the 'leg' of the tank down stream from the dosing location. Coliform counts are determined by a traditional agar plate assay. Residual chlorine levels can be monitored using the standard DPD colorimetric assay or by an amperometric method. Over the period of the trial, the concentration of chlorine in the dose flow can be varied as well as the flow volume itself. As will be appreciated by those of skill in the art, the assay techniques used to determine coliform counts and residual chlorine levels allow the GMPD technique to be optimized for the contact tank and waste water conditions.

Table 1. Exemplary Dosing Liquid Proportions

Dosage Location	Approximate Percentage of Total Dosing Liquid
1	50%
2	28%
3	14%
4	8%
5	variable

Having thus described the invention, it is to be understood that the invention is not to be limited by particular details set forth in the above description or in the claims, as many apparent variations thereof are possible without departing from the spirit or scope thereof.